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Dissolved oxygen and temperature diurnal variations in the Clark Fork River between Deer Lodge and

BRAICO, R.D.

DISSOLVED OXYGEN & TEMPERATURE DIURNAL VARIATIONS IN THE CLARK FORK RIVER BETWEEN DEER LODGE & SUPERIOR MT.

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DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS IN THE CLARK FORK RIVER BETWEEN DEER LODGE AND SUPERIOR, MONTANA FOR THE PERIOD AUGUST 2-3, 1973

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by:

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September 1973

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INTRODUCTION

Small snowpack accumulation in the winter of 72-73, plus a lack of spring rains resulted in below normal stream flows for 1973 in northwestern Montana. Discharge of the Clark Fork above Missoula for July 1973 was 34 percent of the 1955 to 1967 average, and 47 percent of the 1931 to 1960 median (USGS, July 1973). Major Clark Fork tributaries above the Flathead River confluence are the Bitterroot and Blackfoot Rivers and Rock Creek. Discharge of the Bitterroot River near Darby was about 35 percent of the 1953 to 1967 average during June (USGS, June 1973). Flows in Rock Creek and the Blackfoot River were similarly low. Several tributaries to Rock Creek which are normally dry in late August were dry in mid-July according to U. S. Forest Service personnel (1973). Selected stream flows recorded by the U. S. Geological Survey during the study period are summarized in Table 1.

Purpose

When stream flows are low, dissolved oxygen (DO) and temperature levels may reach critical levels for survival of resident game fish. So, dissolved oxygen and temperature were measured at frequent intervals during a 24-hour period at several locations along the Clark Fork. Dissolved oxygen and temperature also were measured for Rock Creek and the Blackfoot and Bitterroot Rivers. Samples for selected heavy metals and biochemical oxygen demand (BOD) analyses were collected at specific sites.

Limitations

Data were collected when dissolved oxygen and temperature levels were thought critical for survival of trout, char and whitefish, the resident game fish. Results may or may not be representative of poorest conditions. As stream flows continued to decline, conditions may have further declined. However, this should have been offset by a trend towards cooler temperatures as fall approached.

A detailed discussion of BOD and heavy metals is outside the scope of this paper. Only limited samples were collected to provide background data. The reader should consult other sources on these subjects.

Acknowledgment

Appreciation is extended to the Montana Department of Fish and Game for their help in this study. In particular, to Randy Smith and Kevin Clader of the Missoula Fish and Game office for collecting data at six of the sampling stations. Appreciation also is extended to Hoerner-Waldorf Corporation for furnishing data collected near the paper plant.

TABLE 1. SELECTED STREAMFLOW DATA

STATION NAME	USGS STATION NO.	LOCATION (1)	STREAMFLOW - CFS MEAN FOR AUG. 2-3, 1973	MEAN FOR 1973 WATER YEAR	AVERAGE DISCHARGE, PERIOD OF RECORD
Clark Fork at Drummond, MT	12331600	11N 12W 31DBD	89	400	--(1)
Clark Fork above Missoula, MT	12340500	13N 18W 19BBB	905	1,788	2,956
Clark Fork below Missoula, MT	12353000	13N 20W 21DAB	1,285	3,118	5,395
Rock Creek near Clinton, MT	12334510	11N 17W 12CA	226	324	--(1)
Blackfoot River near Bonner, MT	12340000	13N 17W 09BDD	502	886	1,636

(1) See Appendix A

(2) Period of record insufficient. Gaging commenced October 1972.

SUMMARY AND CONCLUSIONS

Temperature and dissolved oxygen (DO) diurnal variations were measured at 12 sites along the Clark Fork River between Deer Lodge and Superior (Figure 1). These parameters were also measured at single sampling sites on Rock Creek and the Blackfoot and Bitterroot Rivers. These streams are the major Clark Fork tributaries above Superior. Dissolved oxygen levels above and below the paper plant were measured by Hoerner Waldorf personnel. Samples for biochemical oxygen demand and heavy metals were collected at selected stations.

Results are:

1. Stream temperatures and dissolved oxygen levels at the Rock Creek Bridge station (Clark Fork River) were critical for survival of salmonoids. High temperatures and low DO concentrations coincided 5.25 hours out of the 24-hour period. Increased exposure to direct sunlight due to vegetation removal during highway construction, a large algal population, plus very low flows were believed responsible.

2. Conditions at all other stations appeared satisfactory for salmonoid survival. Undesirable temperatures were recorded at several stations, but DO concentrations were not critical. Minimum DO levels were 6 milligrams per liter or above at all stations except at Deer Lodge and Rock Creek Bridge. Minimum DO concentrations at these stations were 5.9 mg/1 and 5.2 mg/1, respectively.

3. Temperature and dissolved oxygen concentrations in the Clark Fork were improved significantly by Rock Creek.

4. The Clark Fork River below the Bitterroot River confluence is too large to be affected significantly by diurnal variations in air temperature. Maximum water temperature recorded was 73° F. The maximum daily water temperature change measured was 57° F to 64° F (Huson).

5. The effect of discharges from Missoula's sewage treatment on biochemical oxygen demand in the river appeared small. The 24-hour BOD composite taken about one mile below the plant was 2.2 milligrams per liter.

6. Dissolved oxygen concentrations in the Clark Fork were depressed by wastewater leaching from Hoerner Waldorf Corporation holding ponds. Decreases were small, ranging from 0.15 mg/1 to 0.40 mg/1, and resulting DO concentrations do not appear critical (Hoerner Waldorf, 1973).

7. Copper, zinc, lead, cadmium, and iron levels in the Clark Fork probably are below levels which would affect salmonoids adversely.

SOME FACTORS AFFECTING SURVIVAL OF AQUATIC ANIMALS

Temperature

Survival of an organism requires a finite quantity of energy. If a fish is exposed to increased temperatures, more of this energy is expended for basic or resting metabolism. Thus, less energy is available for activities such as food acquisition, growth and reproduction. The optimum temperature range is that span of temperatures within which energy available for activity is maximum (Parker and Krenkel, 1969).

Lethal and preferred temperatures for some species found in the Clark Fork drainage are given in Table 2. Parker and Krenkel (1969) noted some disagreement among authorities. Different acclimation temperatures were used for some experiments and may have caused some of the spread.

Table 2. LETHAL AND PREFERRED TEMPERATURES FOR SOME CLARK FORK RIVER SPECIES (Parker and Krenkel, 1969)

SPECIES	TEMPERATURE - °C LETHAL	PREFERRED
Salmo gardneri (rainbow trout)	-	52 - 61 11 - 16
Salvelinus fontinalis (brook trout)	75 77 24 - 25	54 61 12 - 16
Salmo trutta (brown trout)	78 25.5	54 64 12.4 - 17.6

Provisional maximum temperature recommended by the Federal Water Pollution Control Administration (1) (1968) is 68° F for growth or migration routes of salmonoids.
20° C

Stream temperature is affected by several factors including air temperature, exposure to sunlight, surface area to volume ratio, groundwater inflows and area topography. Creaser (1930) reports temperatures of several trout streams in Michigan and the Smoky Mountains of Tennessee became too warm for trout after adjacent areas were cleared. Adverse stream temperature increases after logging have been recorded in the western United States. Narrow mountain valleys and canyons generally cool quickly after sunset compared to broad, flat valleys between mountain ranges. Thus, topography can greatly affect the time of exposure to direct sunlight and maximum daily air temperatures.

---

(1) Now part of the U. S. Environmental Protection Agency

The following induced temperature changes are allowed by Montana Water Quality Standards (1971)(1, 2) for streams discussed in this report.

1. Between 32° F and 67° F, a maximum 2° F increase is allowed. Above 67° F, the allowed increase is 0.5° F.

2. For temperatures over 55° F, a 2° F per hour decrease is allowed. Between 55° F and 32° F, 2° F maximum is allowed.

3. These induced changes are allowed provided water temperatures are below 40° F in winter and above 44° F during summer.

Dissolved Oxygen

Dissolved oxygen (DO) requirements for egg development, for recently hatched fry and for growth and associated activity of salmonoids are high. How high probably is still undefined for most of these stages. However, the salient point in maintaining a wild fishery is what is required for it to thrive. So, resistance to suffocation by an adult fish may be out of context (FWPCA, 1968).

For cold water fishes, the FWPCA (1968) recommends DO concentrations at or near saturation. Dissolved oxygen levels below 6 milligrams per liter (mg/l) are not recommended if good growth and maintenance of trout plus associated aquatic organisms are to be maintained. Dissolved oxygen levels between 5 and 6 mg/l are permissible for short periods under adverse circumstances if normal daily and seasonal fluctuations occur, and if water quality is favorable (FWPCA, 1968).

Montana Water Quality Standards (1971) (1, 2) for the Clark Fork below Warm Springs Creek (upstream of Deer Lodge) and the Little Blackfoot River do not permit induced reductions of dissolved oxygen below 6 mg/l. Induced reductions below 7 mg/l are not permitted in the remainder of the Clark Fork plus Rock Creek and the Bitterroot and Blackfoot Rivers.

Dissolved oxygen concentrations in streams are inversely proportional to water temperatures. Hence, factors affecting temperature also influence dissolved oxygen. Turbulence, BOD, photosynthesis and respiration also affect DO levels. Rushing mountain streams with DO values frequently exceeding saturation exemplify the effect of turbulence. Biochemical oxygen demand measurement is a bioassay procedure. Classically, it is used to estimate the effect of a biologically degradable waste discharge on the DO of a stream. Photosynthesis occurs when algae and other aquatic plants absorb carbon dioxide and release oxygen during daylight hours. During periods of darkness, respiration occurs and the process is reversed. Thus, DO levels may be very high in late afternoon and very low near dawn if significant quantities of algae and/or other aquatic plants are present.

---

(1) Revised standards have been promulgated but the formal adoption procedure has not been completed.

(2) The standards are applicable after reasonable opportunity for discharges to mix with receiving waters.

High chloride levels decrease DO saturation values. However, chloride levels in the Clark Fork and tributaries considered here are not significant.

Heavy Metals

Dissolved heavy metals, even at very small concentrations, can inhibit growth and propagation of aquatic plants and animals.

Montana Water Quality Criteria (1971) (1,2) for the Clark Fork below Warm Springs Creek, for Rock Creek and for the Blackfoot and Bitterroot Rivers state maximum allowable concentrations shall be less than acute or chronic problem levels as revealed by bioassay or other methods; no increase greater than ten percent of the 96 hour, median tolerance limit (TLm 96) is permitted in any case.

---

(1) Revised standards have been promulgated but the formal adoption procedure has not been completed.

(2) The standards are applicable after reasonable opportunity for discharges to mix with receiving waters.

PROCEDURE

Samples were collected at each of the stations shown in Figure 1. Locations and descriptions are given in Table 3. All samples were collected between 0600 hours on August 2 and 1300 hours on August 3, 1973.

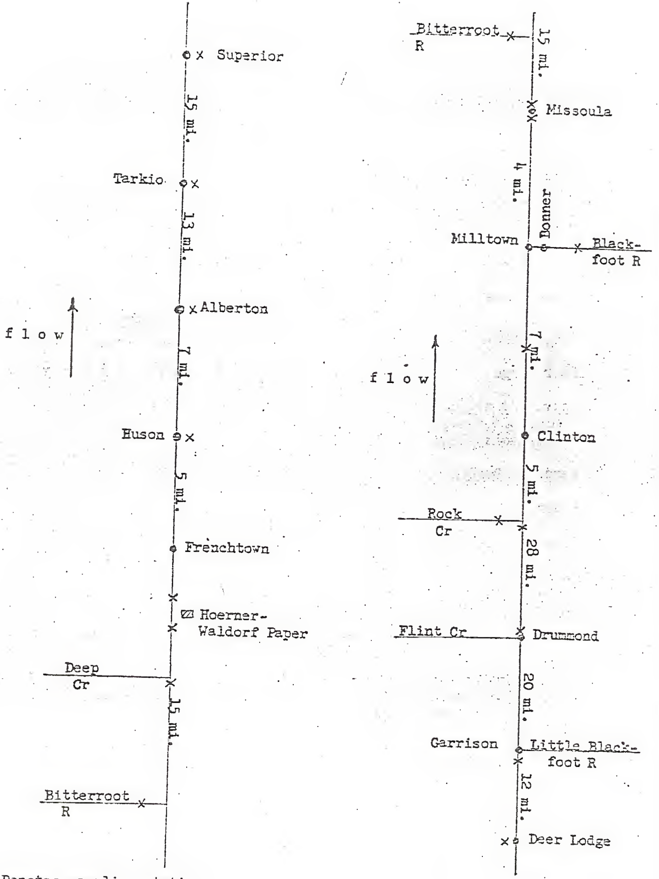
TABLE 3. SAMPLING STATION LOCATION

DESCRIPTION	LOCATION Township	Range	Section	Tract(1)
Clark Fork R near Deer Lodge	7N	9W	4	B
Clark Fork R near Garrison	9N	10W	23	DA
Clark Fork R near Drummond	11N	12W	31	D
Rock Ck approx 3 mi above mouth	11N	16W	19	B
Clark Fork R at Rock Ck Bridge	11N	16W	7	B
Clark Fork R at Turah Bridge	12N	18W	1	D
Blackfoot R at Marco Flats picnic area	13N	18W	12	D
Clark Fork R at Van Buren Bridge	13N	19W	22	C
Clark Fork R approx 1 mi below Missoula sewage treatment plant	13N	20W	23	A
Bitterroot R at Buckhouse Bridge	12N	20W	1	A
Clark Fork R at Harper's Bridge	14N	21W	35	A
Clark Fork R near Huson	15N	22W	28	D
Clark Fork R near Alberton	14N	22W	7	B
Clark Fork R near Tarkio	15N	24W	34	D
Clark Fork R near Superior	17N	26W	27	D
Clark Fork R at Fairbanks(2)	14N	21W	25	CB
Clark Fork R at Marcure Ranch(2)	14N	21N	11	BB

(1) Appendix A. System of Designating Areas within a Section.
(2) Sampling conducted by Hoerner Waldorf Corporation personnel.

Temperature

Air and water temperatures were measured each time a DO sample was collected. All thermometers were mercury filled.



X Denotes sampling station

FIGURE 1. SCHEMATIC FOR CLARK FORK R STUDY SEGMENT

Dissolved Oxygen

Samples for DO were collected every two to four hours at most stations. The azide modification of the iodometric method of analysis (Standard Methods, 1971) was used. Reagents were added in the field and samples were titrated within six hours of collection.

Biochemical Oxygen Demand

Biochemical oxygen demand 24-hour composites were collected at six Clark Fork sampling stations (Table 4).

TABLE 4. SUPPLEMENTAL PARAMETERS

STATION	PARAMETER					
	BOD_5	Fe	Zn	Cu	Pb	Cd
Deer Lodge		X	X	X	X	X
Approx. 1 mi. below Missoula sewage treatment plant	X					
Harper's Bridge	X	X	X	X		X
Huson	X					
Alberton	X					
Tarkio	X					
Superior	X		X	X		X

All BOD samples were iced immediately after collection. Sampling intervals correspond to those for DO and temperature. Some samples were field composited; others were composited by the laboratory staff.

BOD samples were transported to the laboratory in Helena for incubation at 20° C for five days (Standard Methods, 1971).

Heavy Metals

An unfiltered sample was collected at three stations (Table 4) for copper, zinc, lead and cadmium analyses. Each sample was acidified with 5 ml of concentrated, triple-distilled nitric acid. Metal concentrations of unfiltered, acidified samples are reported as total recoverable. Samples were not filtered since turbidities were observed to be low and probably did not exceed 2 Jackson Turbidity Units (JTU). Metal concentrations were determined with an atomic absorption instrument.

RESULTS AND DISCUSSION

Temperature

Water temperatures responded to changes in air temperatures at all stations. Greatest response was recorded on the Clark Fork at Rock Creek Bridge where stream temperatures soared from a low of 63° F at 7 a.m. to 76° F at 5:15 p.m. (Figure 3)(1). The FWPCA (1968) recommended limit of 68° F for growth of salmonoids was exceeded 14.5 hours out of 24 at this station. Several factors probably contributed to this condition:

1. Significant amounts of shade-producing bank vegetation have been lost due to interstate highway construction between Drummond and Rock Creek.
2. Flows were less than half of normal, which caused an increase in surface area to depth rations in channelized segements.
3. There are not significant tributaries between Drummond and Rock Creek. Tributaries frequently are cooler than main streams.
4. Weather during the study period was sunny and hot. Air temperatures into the nineties were recorded at all stations where air temperatures were measured. A brief thundershower around 9 p.m. on August 2 gave some relief from the heat, but water temperatures appeared little affected.

Water temperatures recorded at Deer Lodge did not exceed 68° F (Figure 4). Stream temperatures at both Garrison and Drummond reached 72° F (Figures 5 and 6). Corresponding duration times above 68° F were 11.5 and 8.75 hours at Garrison and Drummond, respectively.

Rock Creek and the Blackfoot River travel through narrow mountain valleys with many small tributaries. Vegetation removal along both streams is minimal. As a result, air temperatures remained cooler longer than at Rock Creek Bridge. Maximum stream temperatures in Rock Creek and the Blackfoot were 68° F and 70° F, respectively (Figures 7 and 8).

Maximum water temperature was 72° F (Figure 9) for the Clark Fork at Turah Bridge, eight miles below the Rock Creek confluence. This is a reduction of 4° F from the maximum obtained in the Clark Fork just above Rock Creek. Length of time during which 68° F was exceeded decreased from 14.5 to 9 hours. Maximum temperature recorded at the Van Buren Bridge station also was 72° F (Figure 10).

A marked decrease in maximum stream temperature (73° F to 59° F) was recorded between the station 1 mile below the sewage treatment plant and

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(1) In order to maintain report continuity, Figures 3 through 19 appear in Appendix B.

Harper's Bridge (Figures 11 and 12). According to Botz (1973), large groundwater flows enter the Clark Fork in this area and cool the river. Maximum water temperature for the Bitterroot River was 74° F (Figure 13). The Bitterroot joins the Clark Fork between these two stations. A gradual warming occurred downstream of Harper's Bridge with equilibrium apparently reached at Alberton. Maximum stream temperatures at Huson, Alberton, Tarkio and Superior were 64° F, 72° F, 70° F, and 72° F, respectively (Figures 14, 15, 16 and 17).

Clark Fork temperatures were least affected by diurnal variations in air temperature below the Bitterroot River confluence. The river becomes quite large in this section, so 35° F short-term changes in air temperature cannot be expected to cause similar responses in water temperature.

Lengths of time during which water temperatures were above 68° F in a 24-hour period at all stations are given in Figure 18. The literature is not specific, but extended periods in which temperatures are a few degrees above 68° F undoubtedly are less severe than brief periods of excessive temperature.

Dissolved Oxygen

Minimum DO levels were 5.9 and 5.2 milligrams per liter (mg/l) in the Clark Fork at Deer Lodge and at Rock Creek Bridge (Figures 3 and 4). Dissolved oxygen levels below 6 mg/l could result in fish kills if other factors are unfavorable (FWPCA, 1968). Water temperatures greater than 68° F and DO concentrations less than 6 mg/l overlapped for 5.25 hours at the Rock Creek Bridge station. The stream was 61° F when the DO concentration was below 6 mg/l at Deer Lodge.

Because stream flows are so low, reaeration through turbulence probably is poor in the Clark Fork above Rock Creek. In addition, the heavy algal populations observed were in the respiration phase when DO levels were critical at Rock Creek Bridge. Photosynthesis caused DO concentrations to reach 9 milligrams per liter during daylight hours at this same location.

Montana Fish and Game Department biologists (1972) predicted DO would be critical in the Clark Fork above Rock Creek if low flows were accompanied by high water temperatures.

DO levels were generally below saturation for all other stations except during periods of maximum photosynthesis (Figures 5 through 18). However, minimum values never dropped below 6 mg/l at any of these stations.

Diurnal DO values recorded below Missoula compare favorably with those at other stations. Depressed DO concentrations were not measured at the station approximately one mile below the Missoula sewage treatment plant discharge. Leachate from Hoerner Waldorf Paper Company ponds did not appear to depress DO levels at Huson and below. A small reduction which varied between 0.15 and 0.40 mg/l DO was recorded by Hoerner Waldorf Corporation (Figure 19) between the Fairbanks and the Marcure Ranch stations.

Biochemical Oxygen Demand

Results of 5-day, 20° C BOD composites are given in Table 5. All composites except that collected about one mile below the Missoula sewage treatment plant were less than 1 mg/1 and typical of stream BOD values. Actual values are probably of little significance. The reliability of depletions less than 2 mg/1 may be questionable (Standard Methods, 1971).

TABLE 5. BIOCHEMICAL OXYGEN DEMAND RESULTS

STATION	BOD - mg/1
Clark Fork R at Harper's Bridge	0.95
Clark Fork R approx 1 mi below Missoula's sewage treatment plant	2.21
Clark Fork R near Huson	0.79
Clark Fork R near Alberton	0.11
Clark Fork R near Tarkio	0.39
Clark Fork R near Superior	0.42

Biochemical oxygen demand was 2.21 mg/1 for the composite sample collected below the treatment plant (noted above). Since flow in the Clark Fork during this time was 920 cubic feet per second (cfs), then the waste load per day was 10,950 pounds of BOD. This BOD is likely the sum of carbonaceous plus nitrogenous BOD because a population of nitrifying organisms probably is established in the Clark Fork below the outfall.

According to sewage treatment plant records, 6,530 pounds of BOD was discharged to the Clark Fork during this period. Biochemical oxygen demand of the effluent was not determined for August 2 and 3, 1973. So, the August 1973 average of 148 mg/1 was used to compute total load. Five day BOD of primary treated sewage is almost exclusively carbonaceous since significant populations of nitrifiers are not established. So, considering the limitations, the two BOD determinations are comparable.

Present facilities for treating Missoula's sewage are inadequate. So, the City has contracted for enlargement of treatment plant capacity and will add secondary treatment equipment.

Heavy Metals

Results of samples collected for copper, zinc, iron, lead and cadmium analyses are given in Table 6. Values reported do not exceed recommended limits for fish and aquatic life by McKee and Wolf (1971) and the FWPCA (1968).

TABLE 6. HEAVY METAL CONCENTRATIONS AT SELECTED CLARK FORK RIVER SAMPLING STATIONS PLUS RECOMMENDED LIMITS FOR FISH AND AQUATIC LIFE

	CONCENTRATION mg/1			RECOMMENDED LIMITS mg/1	
METAL	Deer Lodge	Harper's Bridge	Superior	McKee and Wolf (1971)	FWPCA (1968)
Cu	0.01	0.01	0.01	0.02	1/10 96-hr TLm at any time or 1/30 96-hr TLm 24-hr average
Zn	0.03	0.01	0.01	(1)	1/100 96-hr TLm (Brungs)
Fe	0.05	0.08	0.04	0.3 - 0.7 (Ellis)	None
Cd	0.01	0.01	0.01	(2)	1/30 96-hr TLm at any time or 1/500 96-hr TLm 24-hr average
Pb	0.01	-	-	0.10(3)	-

(1) Afflect (1952) reported that a zinc concentration of 0.04 milligrams per liter in soft water prevented the hatching of rainbow trout eggs.

(2) Lethal concentrations for fish varies from 0.01 to 10 milligrams per liter.

(3) Lethal concentrations are dependent on hardness and DO concentrations.

Specific heavy metal limits for general application are of little value. Research indicates each stream probably is unique since toxicities depend on water chemistry, DO, temperature, and whether eggs, fry, juvenile or adult fish are being studied (McKee and Wolf, 1971; FWPCA, 1968). Toxicity limits for aquatic organism supporting trout populations may be less than for trout. So, setting limits for fish might be academic.

Anaconda Company operations in Butte have released heavy metals to the Clark Fork since the late 1800's. The effect of many years accumulation is expected to have some influence on aquatic organisms even though good treatment has now been provided.

APPENDICES

APPENDIX A

SYSTEM OF LOCATING AREAS WITHIN A SECTION

Wells, springs, water-sampling locations, and stream-gaging locations are assigned numbers based on the system of land subdivision used by the U. S. Bureau of Land Management. The number consists of twelve characters and describes the location by township, range, section, and position within the section. The figure below illustrates the numbering method. The first three characters of the number give the township, the next three characters the range. The next two numbers give the section number within the township, and the next three letters describe the location within the quarter section (160-acre tract) and the quarter-quarter section (40-acre tract), and the quarter-quarter-quarter section (10-acre tract). These subdivisions of the 640-acre section are designated a, b, c, and d in a counterclockwise direction, beginning in the northeast quadrant. If there is more than one feature in a 10-acre tract, consecutive digits beginning with 2 are added to the number. For example, if a water-quality sample was collected in sec.21,T.9N.,R20W, it would be numbered 09N20W21DAA2. The letters DAA indicate that the well is in the NE¼ of the NE¼ of the SE¼, and the number 2 following the letters DAA indicates there is more than one water-quality sampling location in this 10-acre tract.

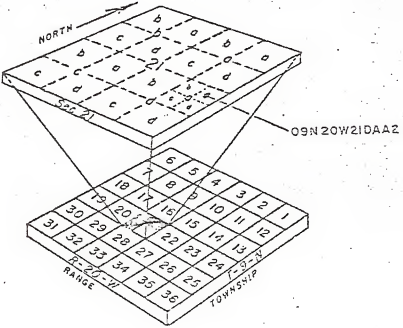

FIGURE 2. LOCATING AREAS WITHIN A SECTION

APPENDIX B. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS AT SAMPLING STATIONS

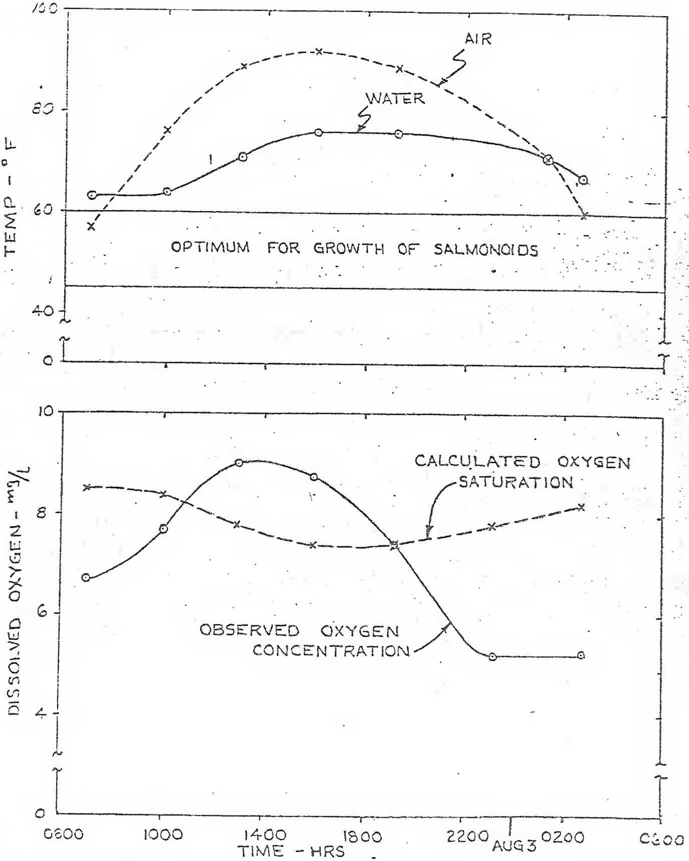

FIGURE 3. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT ROCK CR RD BRIDGE

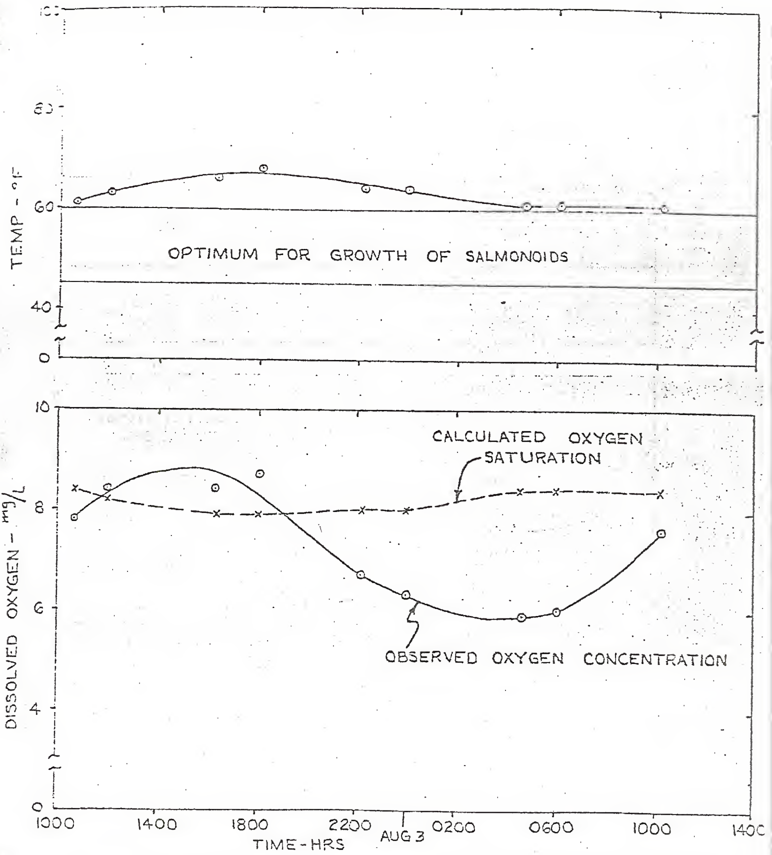

FIGURE 4. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT DEER LODGE

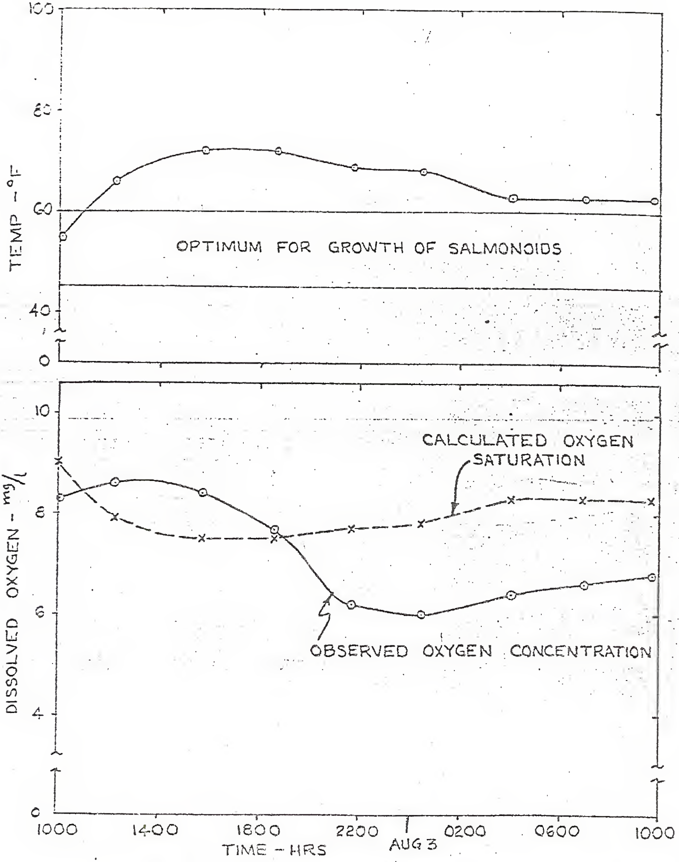

FIGURE 5. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT GARRISON

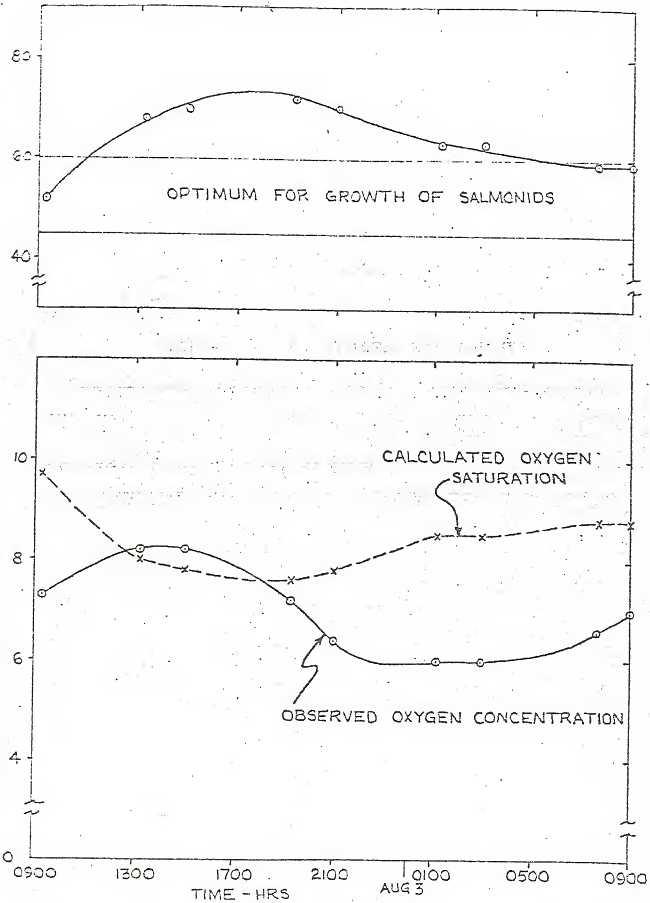

FIGURE 6. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT DRUMMOND

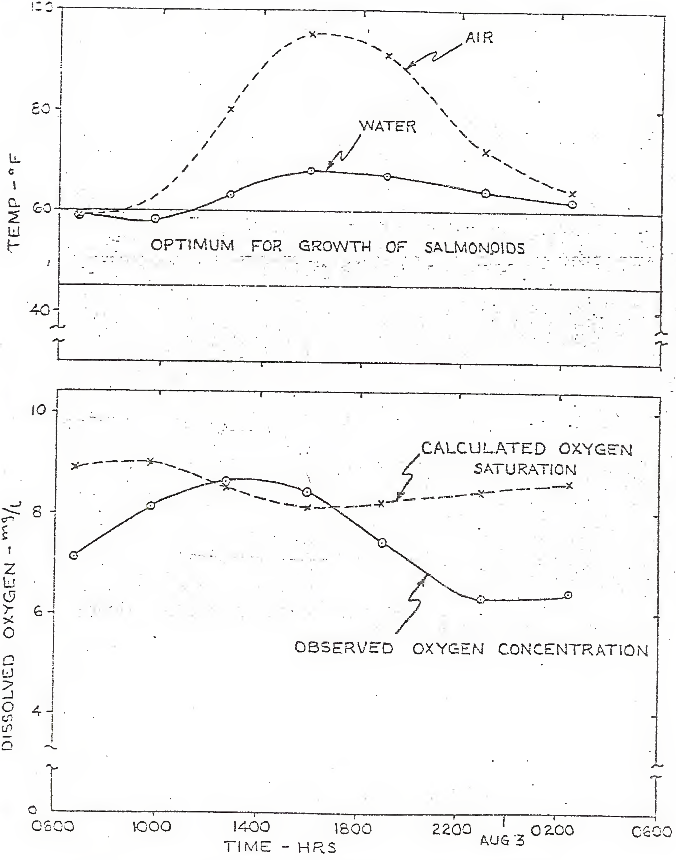

FIGURE 7. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR ROCK CR

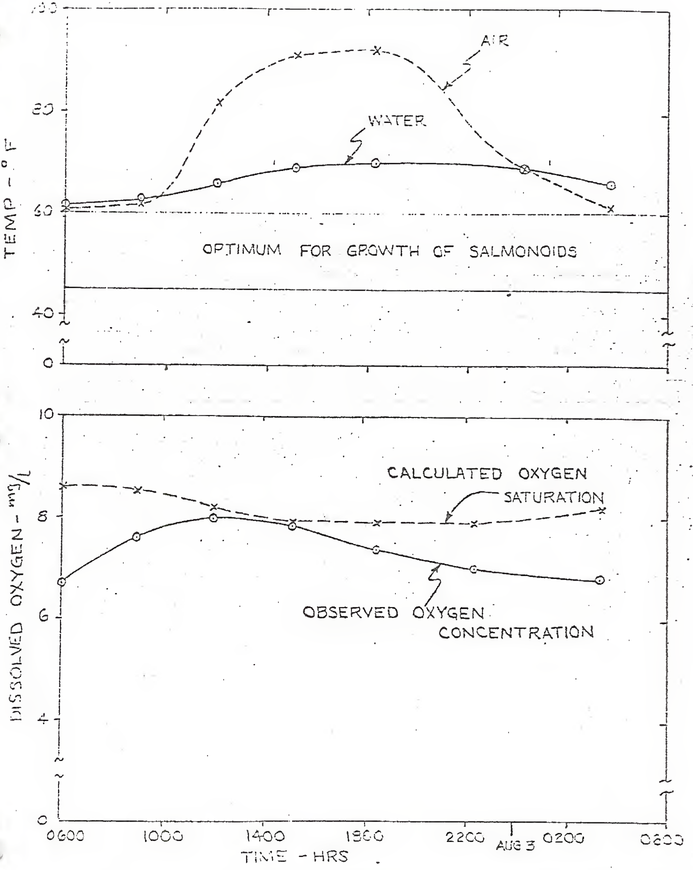

FIGURE 8. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR BLACKFOOT R AT MARCO FLATS PICNIC AREA

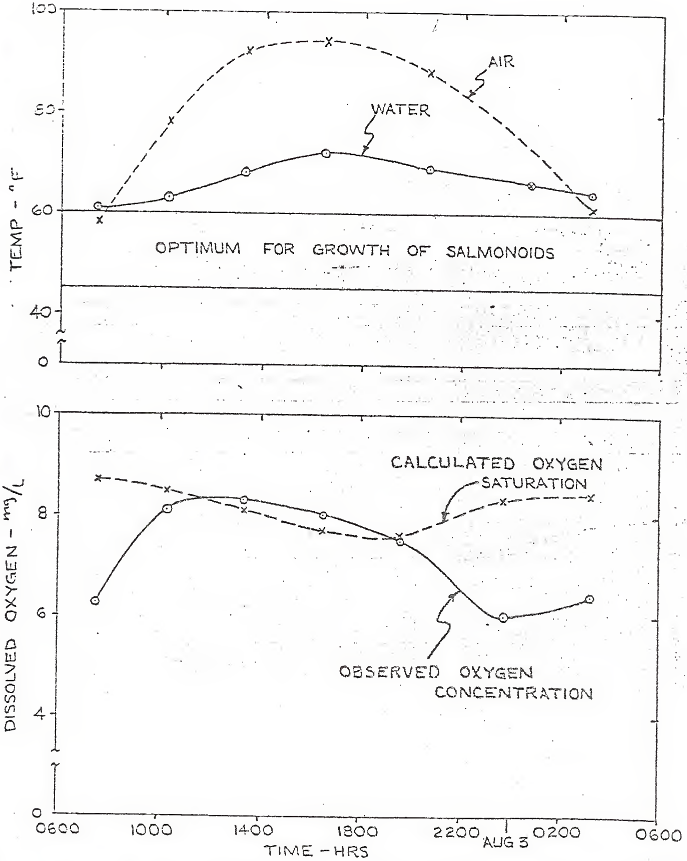

FIGURE 9. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R NR TURAH CAMPGROUND

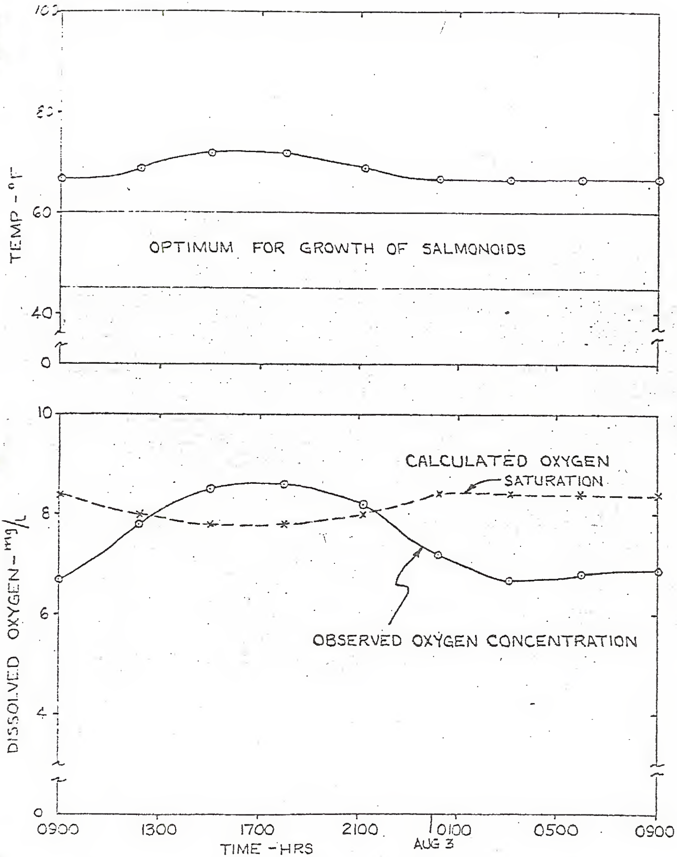

FIGURE 10. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R. AT VAN BUREN BRIDGE, MISSOULA

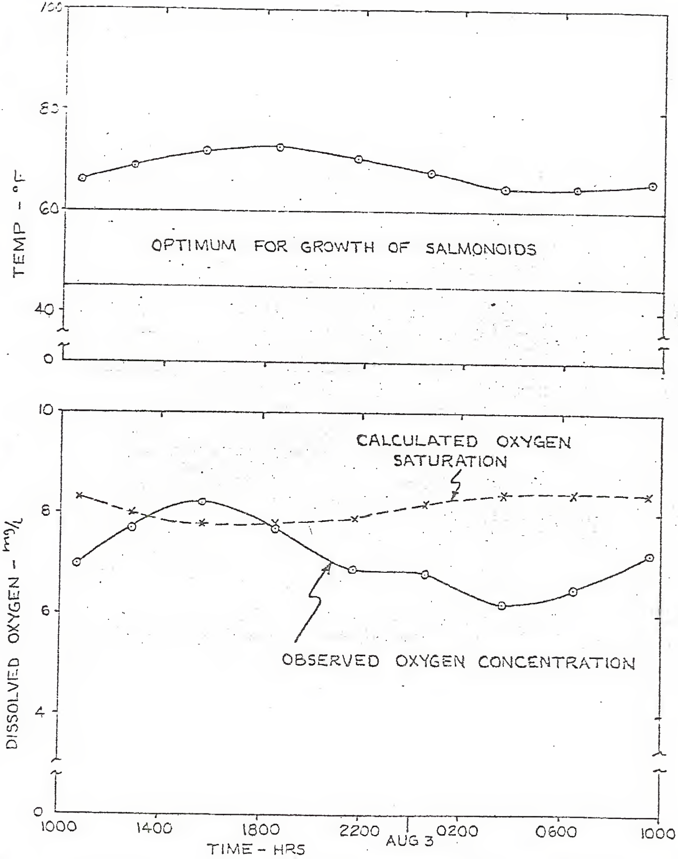

FIGURE 11. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R. APPROX 1 MI BELOW MISSOULA SEWAGE TREATMENT PLANT

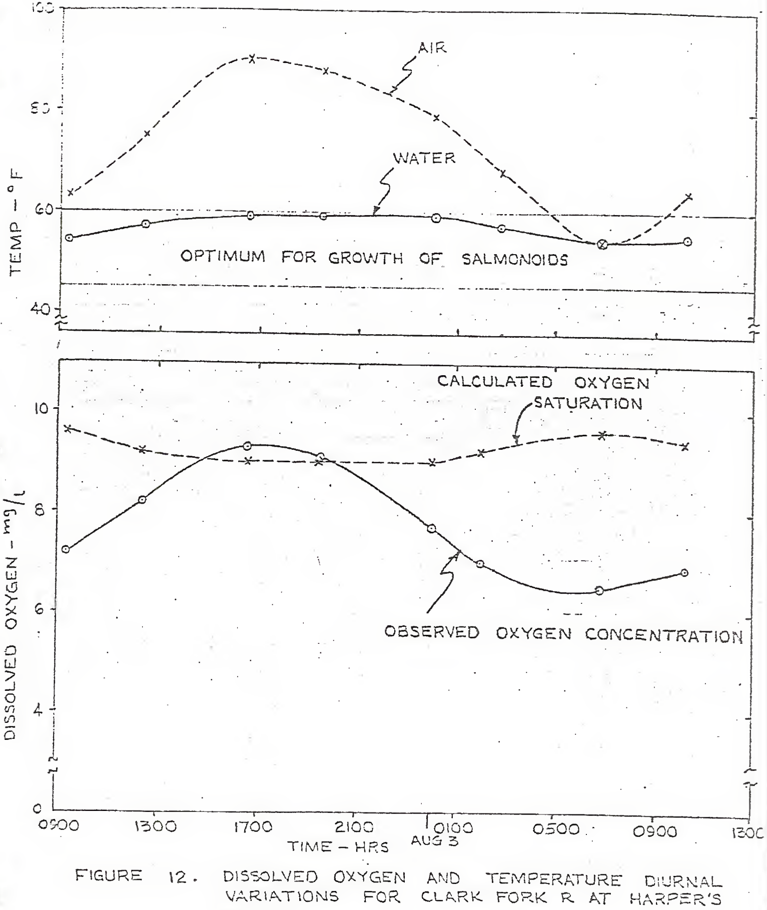

FIGURE 12. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT HARPER'S BRIDGE

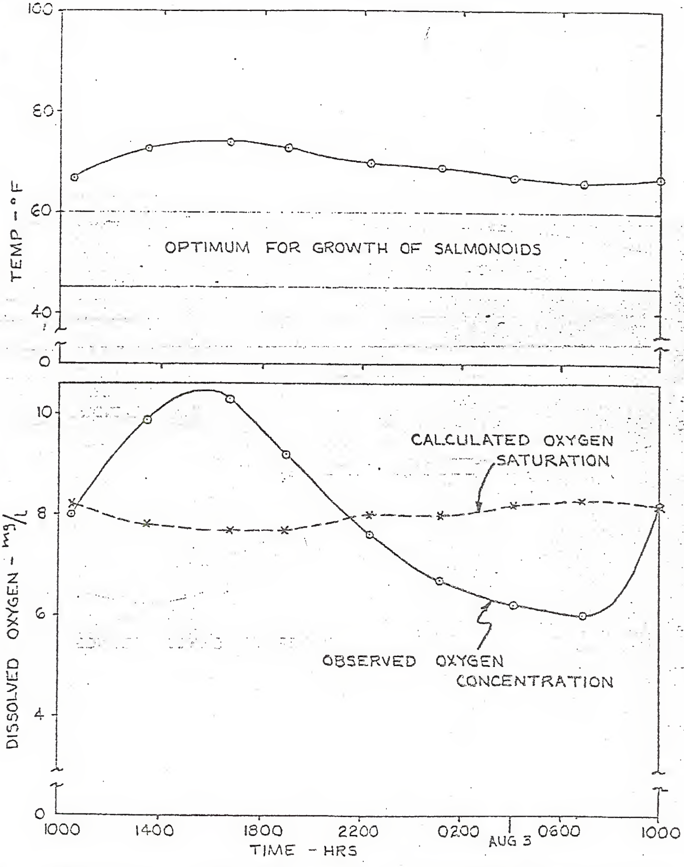

FIGURE 13. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR BITTEROOT R AT BUCKHOUSE BRIDGE NEAR MISSOULA

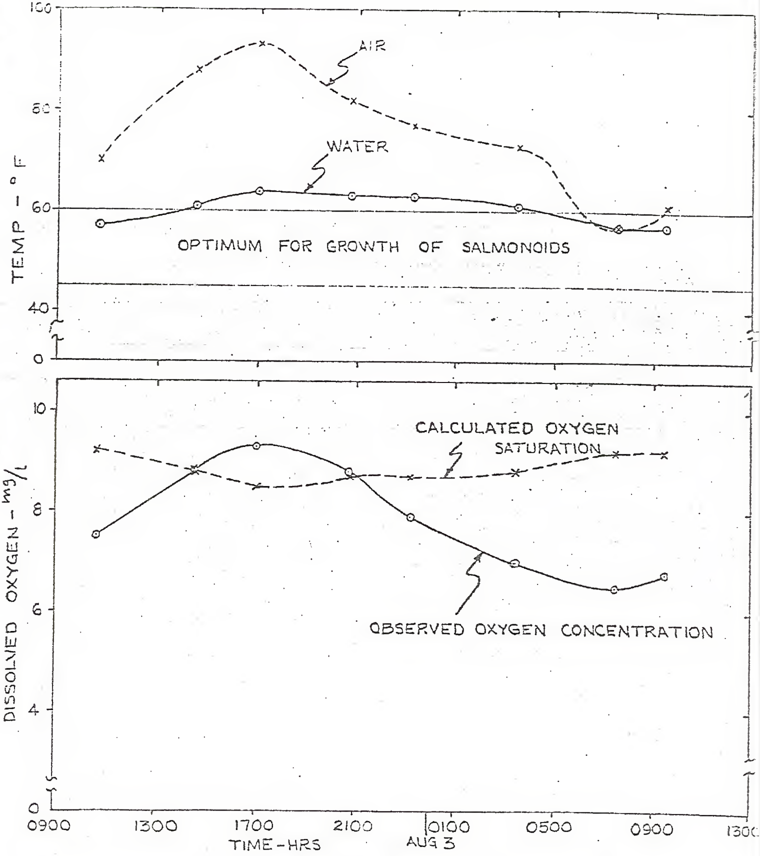

FIGURE 14. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT HUSON

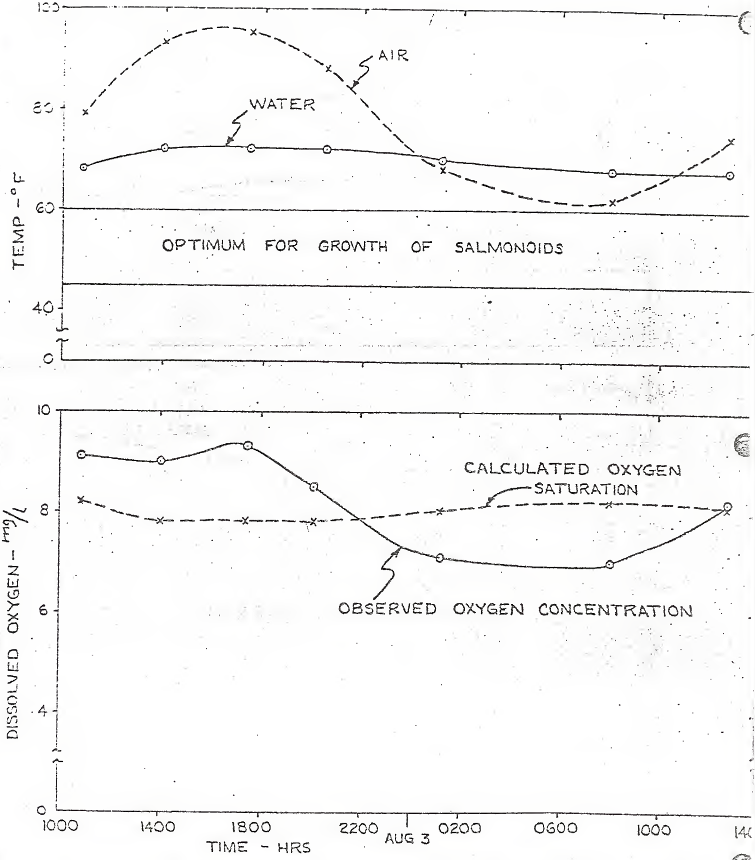

FIGURE 15. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT ALBERTON

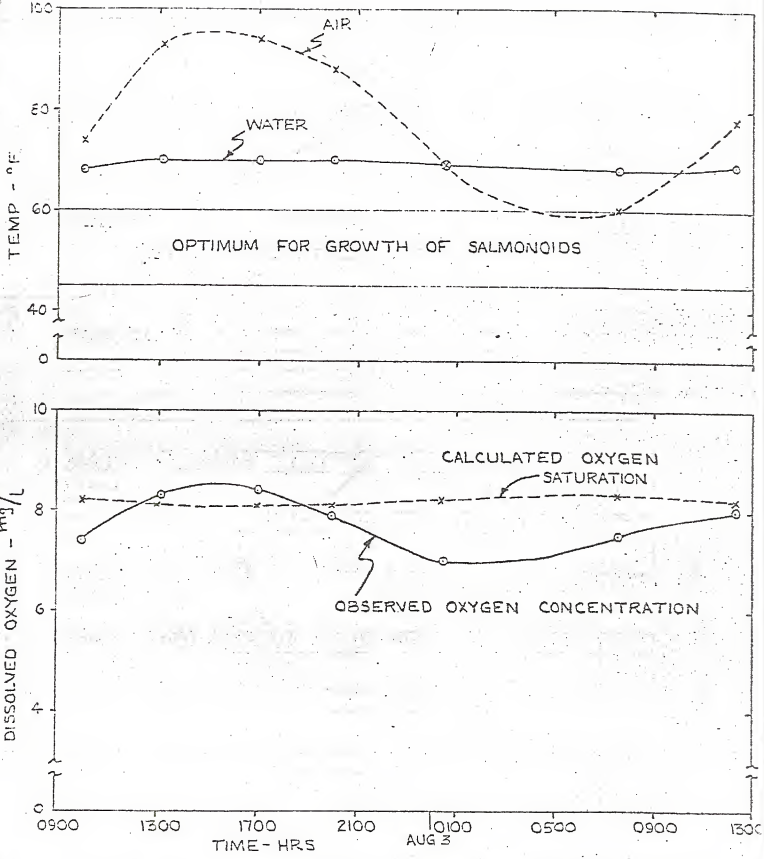

FIGURE 16. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT TARKIO

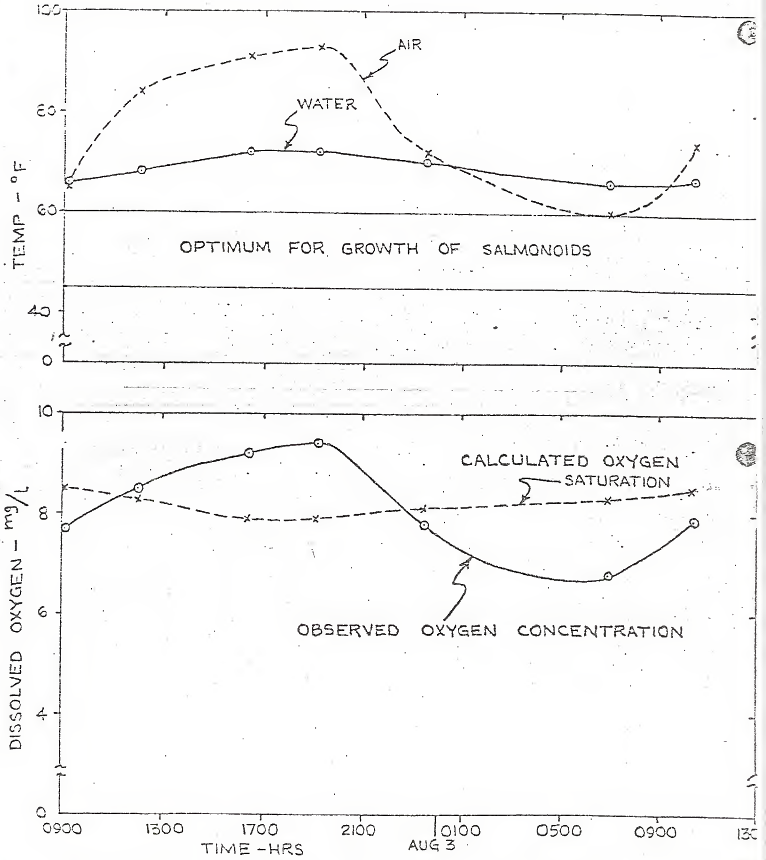

FIGURE 17. DISSOLVED OXYGEN AND TEMPERATURE DIURNAL VARIATIONS FOR CLARK FORK R AT SUPERIOR

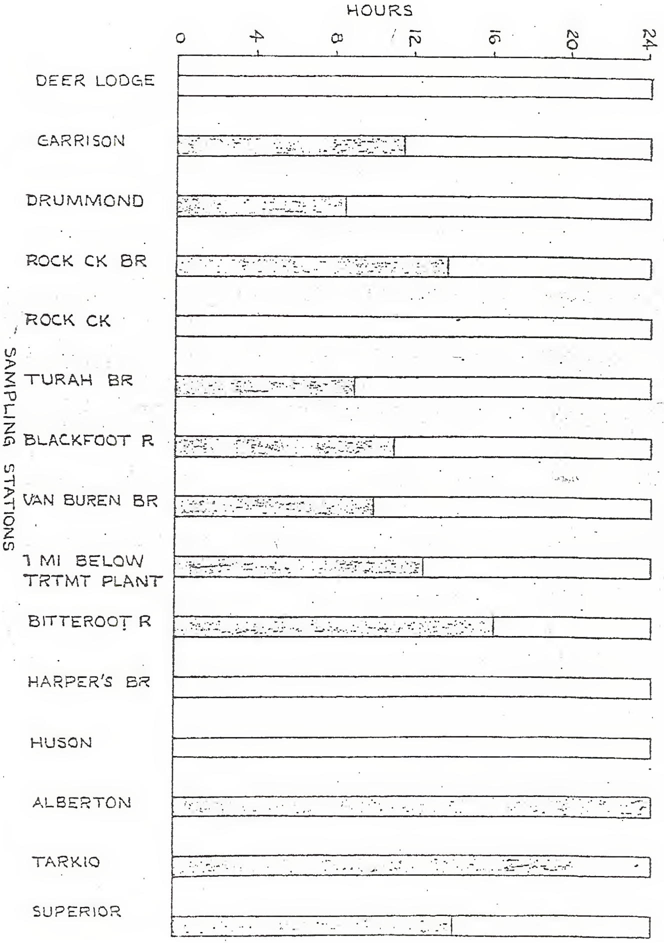

FIGURE 18. PORTION OF DAY WITH WATER TEMPERATURES EXCEEDING 68°F

▨ ABOVE 68°F

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